Design And Implementation of MIMO-FSO Communication System For Disaster Management

Suguna.G[1], Pasupathi.T[2], Jeyamalar.U[3], N.Mangaiyarkarasi[4]
[1]Dept of Electronics and Communication Engineering
[2, 3, 4]Assistant Professor, Dept of Electronics and Communication Engineering
[1, 2, 3, 4] Kings College of Engineering, India

Abstract- *Communication plays an integral role in disaster management. All conventional methods of communication including telephone, radio, and television could be down during disaster. Therefore it is crucially important to have completely functional communication. In this paper, the concept of Free Space Optical Communication (FSOC) is introduced for disaster management, which is one of the most promising wireless communication techniques. FSOC enables us to offer extremely large capacity, high-immunity to interference, low latency, low-energy consumption, large data rate of transmission, reliable and secure communication. Besides all these, FSO faces challenges during transmission due to atmospheric turbulence like rain, fog, snow, cyclones, earthquake etc. Diversity technique is used in this paper to mitigate the fading effects due to the above mentioned effects. This paper proposed a novel method of MIMO-FSO techniques to improve the transmission capacity during disaster. The capacity of MIMO-FSO networks is increased using Polarization Division Multiplexing (PDM). In this paper, the most suitable modulation techniques among OOK, BPSK, OFDM is identified using simulation experiment. The overall performance of the FSOC system is evaluated using Bit Error Rate (BER), Power level at the receiver under various turbulence conditions.*

Keywords- Atmospheric Turbulence, Binary Phase Shift Keying (BPSK),), Multiple Input-Multiple Output (MIMO), Polarization Division Multiplexing (PDM), On-Off Keying (OOK).

I. INTRODUCTION

Disaster Management is a process which deals with the techniques and method to protector preserve lives and property. Disasters are serious disruptions to the functioning of a community that exceed its capacity to cope using its own resources. Disasters can be caused by natural, man-made and technological hazards, as well as various factors that influence the exposure and vulnerability of a community. Communication during and immediately after a disaster situation is a vital component of response and recovery. Despite massive technological changes in recent years, communication problem persist: including system failure, system overload, and incompatibility communication systems used by different agencies. This paper proposes a technique based on free space optics communication during disaster scenario. The optical signal is less prone to rain than fog and hence, this might be useful to establish temporary communication in flood affected areas. The performance of FSO system over Malaga fading channels has proved that effective fading mitigation techniques are required to satisfy the typical (BER) and capacity targets for FSO applications at the range of practical signal-to-noise ratios (SNRs). Wireless radio system use MIMO technique by deploying multiple apertures at the transmitter and the receiver, the FSO system performance can be significantly enhanced. Multiple-Input and Multiple-Output (MIMO) is a method for multiplying the capacity of a radio link using multiple transmission and receiving antennas to exploit multipath propagation. The antennas at each end of the communications circuit are combined to minimize errors, optimize data speed and improve the capacity of radio transmissions by enabling data to travel over many signal paths at the same time. Creating multiple versions of the same signal provides more opportunities for the data to reach the receiving antenna without being affected by fading, which increases the Signal-to-Noise Ratio and error rate. By boosting the capacity of Radio Frequency (RF) systems, MIMO creates a more stable connection and less congestion. At one time, in wireless the term "MIMO" referred to the use of multiple antennas at the transmitter and the receiver. In modern usage, "MIMO" specifically refers to a practical technique for sending and receiving more than one data signal simultaneously over the same radio channel by exploiting multipath propagation. Although this "multipath" phenomenon may be interesting, it's the use of orthogonal frequency division multiplexing to encode the channels that's responsible for the increase in data capacity. MIMO is fundamentally different from smart antenna techniques developed to enhance the performance of a single data signal, such as beam forming and diversity.This paper discusses the performance of MIMO-FSO communication system using PDM under different atmospheric turbulence conditions. In MIMO FSO, capacity of the link is increased by combining polarization division multiplexing (PDM) with suitable modulation techniques. This paper details the Free Space Optical Communication (FSOC) also known as wireless Line of Sight (LoS) optical communication technology that uses light for the transmission of information through air or vacuum. FSOC links have some distinct advantages over conventional microwave, Radio Frequency(RF) and Optical Fiber Communication System by virtue of their very high carrier frequencies that permit large capacity, enhanced high security, high data rate etc., This paper implemented a diversity technique of FSO and since MIMO-FSO techniques outperforms the other techniques, it's chosen for the analysis of the disaster management scenario. The capacity of MIMO-FSO networks is increased using Polarization Division Multiplexing (PDM).

II. EXISTING SYSTEM

The existing system introduced a technique based on free space optics. The optical rain is less prone then fog and hence, this mitigate be useful to establish temporary communication in flood- affected area distortion. The simple form of diversity technology is Single Input Single Output (SISO) where the transmitter and receiver operate with a single antenna. Single Input and Multiple Output (MIMO) is the technology in which the receiver has multiple antennas and transmitter has a single large aperture SIMO is called receiver diversity. Multiple Input Single Output (MISO) is called as transmit diversity technology which has got multiple transmitting antennas and single receiver antenna. Multiple input and multiple output (MIMO) uses multiple antenna at both transmitter and receiver sides. The existing system performs the MISO-OFDM system using PDM under different atmospheric turbulence conditions.

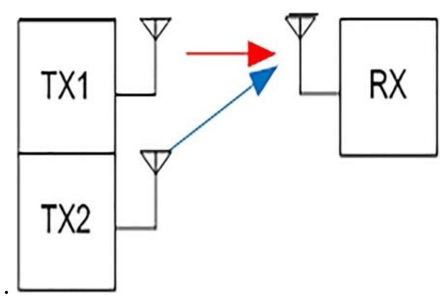

Fig 1 Block Diagram of Existing system

In MISO FSO, capacity of the link is increased by combining polarization division multiplexing (PDM).This project also discusses the system performance of MIMO-FSO using QPSK modulation. MIMO-FSO systems, the performance analysis is made over turbulence channels. This existing system introduced a method to improve the capacity of MISO and MIMO-OFDM FSO networks transmission using PDM.

III. PROPOSED SYSTEM

Proposed technology overcomes the existing technology by developing the diversity technique with different modulation schemes OOK, BPSK & OFDM, which is useful to enhance the performance of the proposed system. The method is useful to establish temporary communication in flood affected areas. During the disasters, computer can be located in buildings or temporary shelters. The entire setup can be placed on the roof of the buildings from which connection can be established to a remote location. Binary information are generator through PRBS using VHDL module which can fed random binary data to the FSO transmitter. FPGA receive information and fed to the FSO transmitter circuit. The FSO transmitter circuit comprises the modulator and laser source. The modulation (OOK, BPSK & OFDM) schemes are employed to generate the modulated signal. The modulated signal is fed to the laser source which converts the electrical energy into optical signal. The optical signal is passed through the atmospheric channel. The receiver section consists of photo detector and diversity techniques. The photo detector receives multiple wavelengths from transmitter. Diversity techniques consist of Equal Gain Combining (EGC), decision device and switching logic. EGC and decision device combines multiple inputs and select the highest output. Switching logic act as a switch and it directly connected to the high range output.

The modules developed are described in future section. The overall module of proposed system shows in figure1.

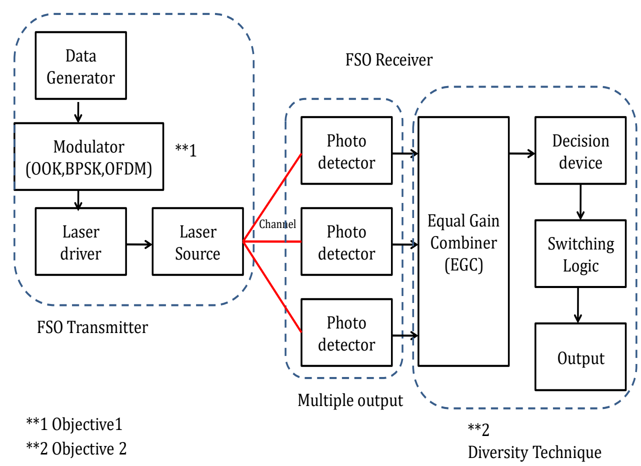

Fig 2 Block Diagram of Proposed system

A. PRBS generator

PRBS are useful in various field of digital communication such as testing of transmission system, BER measurement etc. It has lot of uses in different application mainly with digital communication and test pattern generation such as VLSI testing to generate the binary sequence. The main functional unit of PRBS generator is Linear Feedback Shift Register(LFSR) which is a group of flip flop connected in series with the feedback mechanism. Depending upon the number of flip flops used, it can produce same number of outputs bit in an instance. The total number of instance it can generate is known as maximal length sequence.

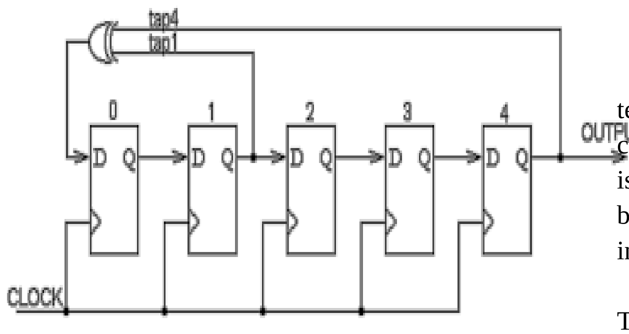

Fig 3 Block Diagram of PRBS Generator

B. Modulators

1. OOK Modulator*:*

ON-OFF Keying (OOK) is the most widely used modulation technique due to its simplicity and easier to implement. OOK is a form of modulation in which a '0' is represented by switching off the laser source and '1' is represented by switching on the laser source. At the receiver the '1' or '0' is decision is determined by the received energy being above a threshold.

The modulator pulse when signal '1' is present as

$$P_1(t) = A\cos 2\pi f_c t, \text{ when } 0<t<T_b \qquad (1)$$

where,

A is the amplitude.
f_c is the carrier frequency.
T_b is the bit duration.

When signal '0' is present as:

$$P_0(t) = 0 \qquad (2)$$

Fig 3 Simulation output of OOK modulator

2. BPSK Modulator*:*

Phase modulation is a linear baseband modulation technique in which the message modulates the phase of a constant amplitude signal. Binary Phase Shift Keying (BPSK) is a two phase modulation scheme, where the 0's and 1's in a binary message are represented by two different phase states in the carrier signal.

The general form for BPSK follows the equation:

$$sn(t)= (\sqrt{2Eb/Ns})\cos(2\pi fct+\phi n) \qquad (3)$$

This yields two phases, 0 and π. In the specific form, binary data is often conveyed with the following signals:
For binary "0"

$$S_0(t)= (\sqrt{2Eb/T}_b \cos(2\pi fct+\pi)$$
$$= - (\sqrt{2Eb/T}_b \cos(2\pi fct) \qquad (4)$$

For binary "1"

$$S_1(t)= (\sqrt{2Eb/T}_b \cos(2\pi fct) \qquad (5)$$

For $(n-1)Tb \leq t \leq n\, Tb$, n = 1,2, 3,…

where,
$\phi_n = \pi m$, $m \in \{0,1\}$.
E_b is the energy per bit.
T_b is the bit duration.
f_c is the carrier frequency.

In MATLAB, the baseband representation of a BPSK signal is

$$sn(t)= e-i\phi n = \cos(\pi n) \qquad (4)$$

The BPSK signal has two phases: 0 and π. The probability of a bit error in an AWGN channel is

$$Pb = Q\left(\sqrt{2Eb}/Ns\right) \qquad (5)$$

. where N_0 is the noise power spectral density

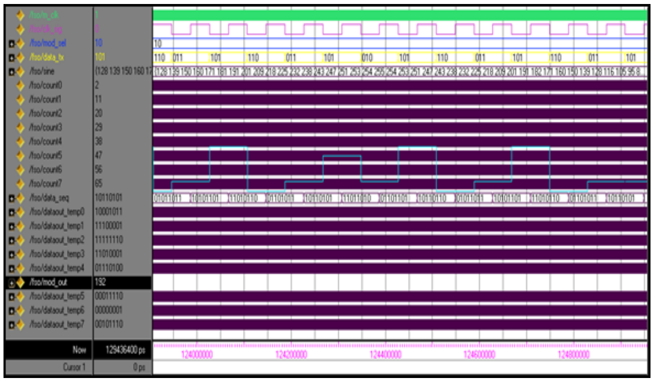

Fig 3 Simulation output of BPSK modulator

3. OFDM Modulator:

The low-pass equivalent OFDM signal is expressed as:

$$V(t)=\sum_{k=0}^{N-1} X_k e^{j2\pi kt/T},\ 0 \le t < T \qquad (6)$$

Where,

$\{X_k\}$ are the data symbols, is the number of subcarrier, and is the OFDM symbol time. The subcarrier spacing of makes them orthogonal over each symbol period.

This property is expressed as:

$$\frac{1}{T}\int_0^T (e^{j2\pi k_1 t/T})^*(e^{j2\pi k_2 t/T})\, dt = \frac{1}{T}\int_0^T (e^{j2\pi(k2-k1)})t/T\, dt = \delta_{k1k2} \qquad (7)$$

Where (.)* denotes the complex conjugate operator and δ kronecker delta..

The OFDM signal with cyclic prefix is thus:

$$V(t) = \sum_{k=0}^{N-1} X_k e^{j2\pi kt/T},\ -T_g \le t < T_g \qquad (8)$$

The low-pass signal above can be either real or complex-valued. Real-valued low-pass equivalent signals are typically transmitted at baseband-wire line applications such as DSL use this approach. For wireless applications, the low-pass signal is typically complex-valued; in which case, the transmitted signal is up-converted to a carrier frequency.

In general, the transmitted signal can be represented as:

$$S(t) = \{v(t)e^{j2\pi fct}\} \qquad (9)$$

$$= \sum_{k=0}^{N-1} !Xk!\ \cos(2\pi[f_c+k/T]t + \arg[X_k]) \qquad (10)$$

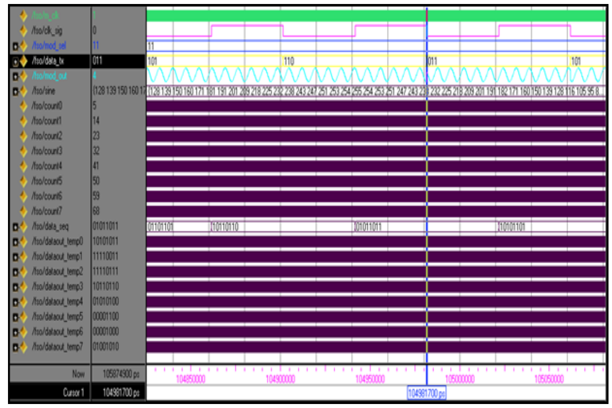

Fig 3 Simulation output of OFDM modulator

C. D*iversity techniques*

In such a system, the receiver is provided with Diversity is a powerful communication receiver technique that provides wireless link improvement at a relatively low cost. Diversity techniques are used in wireless communications systems to primarily to improve performance over a fading radio channel multiple copies of the same information signal which are transmitted over two or more real or virtual communication channels. Thus the basic idea of diversity is repetition or redundancy of information. In virtually all the applications, the diversity decisions are made by the receiver and are unknown to the transmitter.

1. Equal Gain Combiner

Various techniques are known to combine the signals from multiple diversity branches. In equal gain combining, each signal branch weighted with the same factor, irrespective of the signal amplitude. However, co-phasing of all signals is needed to avoid signal cancellation. Thus, EGC is simpler to implement than Maximum Ratio Combining (MRC). The adaptively controller amplifiers / attenuators are not needed. Moreover, no channel amplitude estimation is needed. The average SNR improvement of EGC is typically about 1 dB worse than with MRC, but still much better than without diversity.

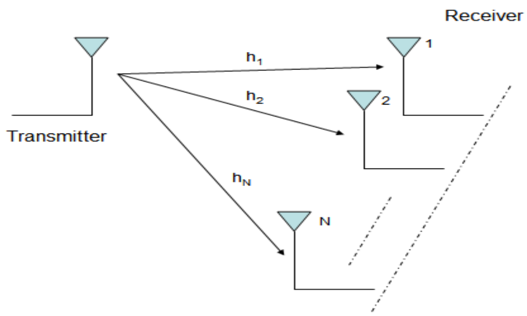

Fig: 4 Equal gain combining

In EGC diversity technique, *N* number of photo detectors in the receiver is realized. The signals from *N* photo detector are unified and then demodulated. The electrical SNR of the FSO system with EGC can be described as

$$SNR_{EGC} = (R^2A^2/2N\sigma^2)\sum_{n=1}^{N} h^2{}_n \qquad (11)$$

The probability of conditional BER can be defined as,

$$P_{ec,\ EGC(h)} = Q(\sqrt{SNR_{EGC}}) \qquad (12)$$

$$P_{ec,\ EGC(h)} = 0.5\times erfc(RA/2N\sigma\sqrt{\textstyle\sum_{n=1}^{N} h^2{}_n}) \qquad (13)$$

The average BER of MIMO-FSO system with EGC diversity can be expressed as,

$$Pe,\ EGC = \int_0^\infty erfc\ (RA/2N\sigma\sqrt{\textstyle\sum_{n=1}^{N} h_n{}^2})\ f_h(h)d \qquad (14)$$

2.* Wavelength Diversity*:

Wavelength diversity (WD) is a technique which does not pose a limit on maximum achievable bit rate but still leads to significant power reduction compared to spatial diversity. Also, the overhead due to error correction coding schemes is reduced which effectively increase the performance.

Used to improve performance over fading radio channel. In system, receiver is provided with multiple copies of the same information signal which are transmitted over 2 or more channel.It used to transmit same bits of information over different wavelength simultaneously. It accurately detected by the respective wavelength receiver.

D. P*olarization Division Multiplexing*

Polarization Division Multiplexing (PDM) is a physical layer method for multiplexing signals carried on electromagnetic waves, allowing two channels of information to be transmitted on the same carrier frequency by using waves of two orthogonal polarization states. It is used in microwave links such as satellite television downlinks to double the bandwidth by using two orthogonally polarized feed antennas in satellite dishes. It is also used in fiber optic communication by transmitting separate left and right circularly polarized light beams through the same optical fiber. Polarization techniques have long been used in radio transmission to reduce interference between channels, particularly at VHF frequencies and beyond

.

IV. SIMULATION RESULTS

The VHDL coding for the different modules is developed using XILINX 12.1 and the simulation result was verified using MODELSIM Simulator. This section discusses the results for modulation schemes viz OOK, 4-PSK and OFDM.

A. *OOK modulation:*

The Simulation result for OOK is shown in Fig 5 On-Off Keying involves transmitting the high frequency carrier when '1' is present in the data signal and absence of carrier when '0' is present in data signal. The system clock is shown in violet and clock is shown in green, the mod_sel is shown in yellow and is chosen as '01' for this scheme and data is shown in blue and finally the output is shown in red. As we can see the output is high when the LSB of the data is high and low when the data is low hence representing On-off keying.

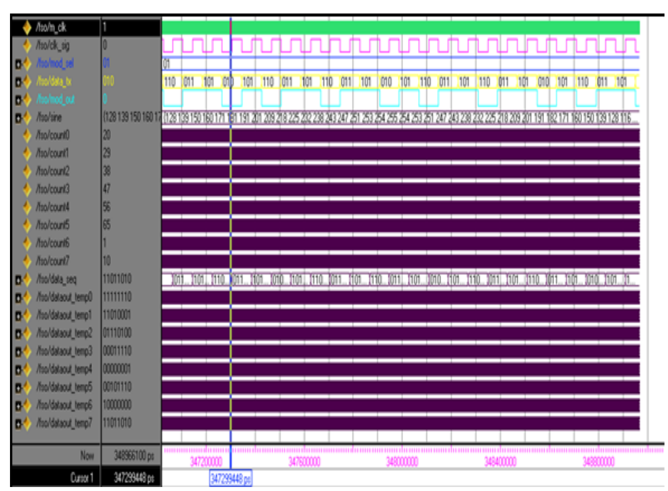
Fig: 5 Simulation Result for On-off Keying

B. *BPSK Modulation*:

BPSK is a modulation scheme where various amplitude levels are used to indicate the data bits. 3 data bits are chosen to be transmitted which corresponds to 8 different amplitude levels. The mod _sel chosen 10 for this scheme and the clock signal is given to the appropriate input; the output consists of generation. The output is shown in red. The Fig shows the variation of the amplitude of the waveform thus indicating the BPSK.

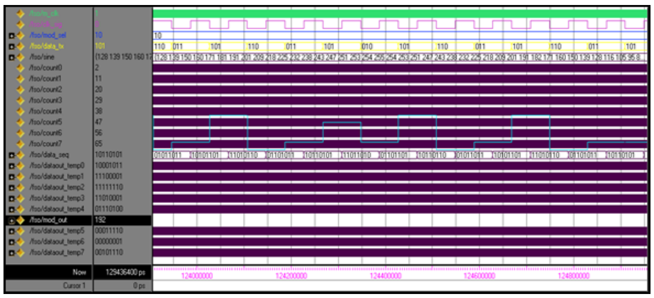

Fig:6 Simulation result of BPSK Modulation

C. OFDM M*odulation:*

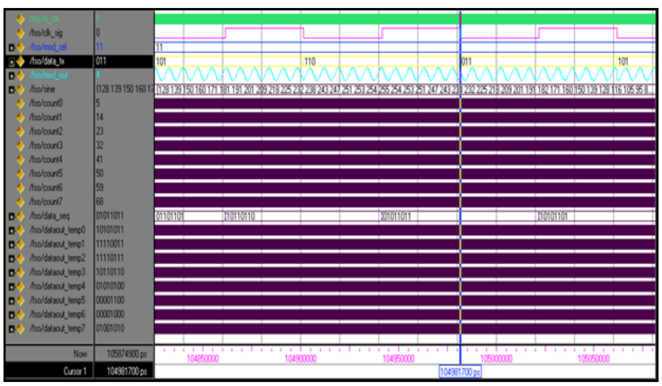

Fig:7 Simulation result for 8-PSK scheme

D. ***Pseudo Random Binary Sequence (PRBS) generator:***

Fig: 8 Simulation of PRBS Generator

E. ***Simulation result for Equal Gain Combiner (EGC):***

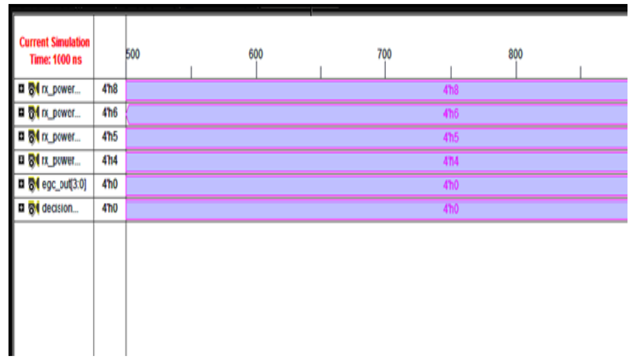

Fig: 9 Simulation Result of EGC

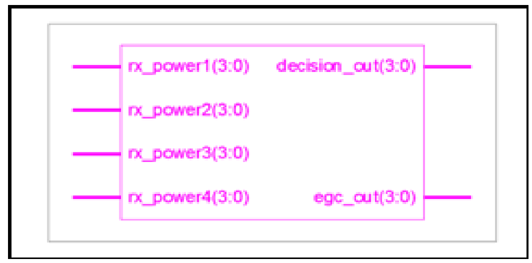

Fig: 10 RTL Schematic

F. ***Simulation result for received power:***

To study the real time performance of Free Space Optical Communication (FSOC) and the power is calculated. The Fig 11 represents the received data which is transmitted with different modulation techniques. Due to atmospheric turbulence, power in the signal is attenuated heavily. This can be mitigated using proposed system.

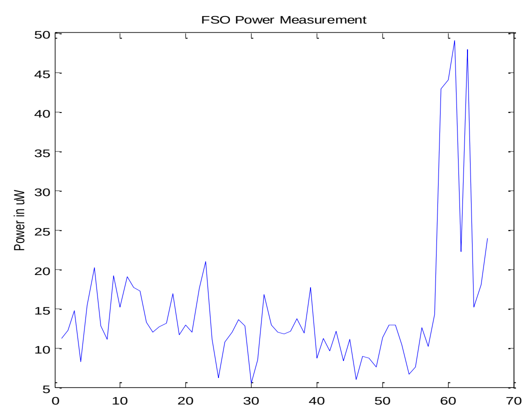

Fig:11 Simulation result of received power

This chapter discussed the results and analysis obtained through Xilinx simulation tool. The implementation of various modulation schemes were performed using the VHDL. The performance analysis for various modulation schemes was experimentally verified. Also the simulation results of Equal Gain Combiner (EGC) is presented.

V. CONCLUSION

In this paper, a novel method for disaster management using FSO with modulation scheme is proposed. This paper implemented a method to improve the capacity of MIMO-FSO communication using diversity technique. In existing system, due to atmospheric turbulence FSO faces many challenges during data transmission. The proposed system overcomes the existing system by using suitable modulation techniques (OOK, OFDM and BPSK). Diversity technique is used to increase capacity and performance of the system. The application of the proposed system can be applicable on remote sensing area, military and etc., The system is analyzed for weather turbulence which can be applied for disaster management scenario.

REFERENCES

[1] Muhammad Adanan Khan, Intelligent FSO link for communication in natural disaster empowered with Fuzzy inference system, International Journal on Electrical Communication and Computer Engineering, July (2019)

[2] M.P.Ninos, H.E.Nistazakis, E.Leitgeb and G.S.Tombras, Spatial diversity for QAM OFDM RoFSO links with non zero bore sight pointing errors over atmospheric turbulence channels, Journal of Modern Optics, Volume 66, (2019)

[3] G.K.Varotsos, H.E.Nistazakis, Ch.K. Volos and G.S.Tombras, FSO link with diversity pointing error and temporal broadening of the pulse over the weak to strong Atmospheric Turbulence channel, Elsevier, Optic-International Journal for Light and Electron Optics, Vol.127,Iss.6,pp.342-3409,(2016).

[4] H.E.Nistazakis, A.N.Stassinakis, S.Sheikh Muhammad, G.S.Tombras, BER estimation for Multi Hop RoFSO QAM & PSK OFDM communication system over Gamma or exponentially modeled Turbulence Channel," Elsevier optics & Laser Technology,Vol.64,pp.106-112, (2014).

[5] Li, Z.Q., et.al: Comprehensive study of optical, physical, chemical, and radiative properties of total columnar atmospheric aerosols over China: An overview of Sun–Sky Radiometer Observation Network (SONET) measurements. Bull. Amer. Meteor. Soc. 99, 739–755 (2013)

[6] Yu, B., Jia, W., Zhou, C., Cao, H., Sun, W.: Grating imaging scanning lithography. Chin. Opt. Lett. 11, 080501 (2013)

[7] Koebele, C., et.al.: Impact of transmitter bandwidth on transmission performance of coherent 112-Gb/s PDM-QPSK systems. Photon. Technol. Lett. 22, 1859 (2010)

[8] Liu, X., Chraplyvy, A.R., Winzer, P.J., Tkach, R.W., Chandrasekhar, S: Phase-conjugated twin waves for communication beyond the Kerr nonlinearity limit. Nat. Photon. 7, 560–568 (2013)

[9] Zhang, J.W., Yu, J.J., Chi, N.: Transmission and full-band coherent detection of polarization-multiplexed all-optical Nyquist signals generated by Sinc-shaped Nyquist pulses. Sci. Rep. 5, 13649 (2015)

[10] Brixner, T., Krampert, G., Pfeifer, T., Selle, R., Gerber, G., et al.: Quantum control by ultrafast polarization shaping. Phys. Rev. Lett. 92, 208301 (2004)

[11] Sato, M., Higuchi, T., Kanda, N., Konishi, K., Yoshioka, K., et al.: Terahertz polarization pulse shaping with arbitrary feld control. Nat. Photon. 7, 724–731 (2013)

[12] Colas, D., Dominici, L., Donati, S., Pervishko, A.A., Liew, T.C.H., et al.: Polarization shaping of Poincaré beams by polariton oscillations. Light Sci. Appl. 4, e350 (2015)

[13] Zhou, Y., Liu, Y., Guo, L.: A novel polarization division multiplexing system Employing polar-ofdm with subcarriers interlaced. In: 2015 14th International Conference on Optical Communications and Networks (ICOCN) @ Nanjing, China (2015)

[14] Elgala, H., Little, T.D.C.: P-OFDM: spectrally efcient unipolar OFDM. In: Optical Fiber Communications Conference and Exhibition, pp. 1–3 (2014)

[15] Kale, S., Pagare, R.A.: OFDM-PON transmission in fber optical network. In: Conference on Power, Automation and Communication (INPAC), pp. 85–88 (2014)

[16] Al-Habash, M.A., Andrews, L.C., Phillips, R.L.: Mathematical model for the irradiance probably density functions of a Laser beam propagating through turbulent media. Opt. English 40(8), 1554–1562 (2001)

[17] Chatzidiamantis, N.D., Karagiannidis, G.K.: On the distribution of the sum of Gamma-Gamma variates and applications in RF and optical wireless communications. IEEE Trans. Commun. 59(5), 1298–1308 (2011)

[18] Black, D.M., Reudink, D.O.: Some characteristics of mobile radio propagation at 836 MHz in the Philadelphia area. IEEE Trans. Veh. Technol. 21(2), 45–51 (1972)

[19] Gottumukkala, V.K.V., Minn, H.: Ergodic capacity analysis of MISO/SIMO-OFDM with arbitrary antenna and channel tap correlation. IEEE Trans. Veh. Technol. 62, 3062–3068 (2013)

[20] Marinos, D., Nistazakis, H.E., Aidinis, K., Tsilis, E., Tombras, G.S.: SISO and MISO architecture investigation for wireless optical OFDM transmission. Int. J. Sens. Netw. DataCommun.1,1–5(2012).